DOCUMENT RESUME

ED 201 487 SE 034 821

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TITLE Patterns of Reasoning: Correlational Thinking.
PUB DATE Apr 81
NOTE 15p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (54th, Grossinger's in the Catskills, Ellenville, NY, April 5-8, 1981). Contains occasional marginal legibility.

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Abstract Reasoning; Chronological Age; *Cognitive Development; College Science; College Students; Correlation; Elementary School Science; Elementary Secondary Education; Higher Education; *Logical Thinking; *Science Education; Secondary Education; Secondary School Science; Secondary School Students
IDENTIFIERS Piagetian Stages; *Science Education Research

ABSTRACT

Reported are results of a study proposing to determine whether developmental patterns in correlational reasoning could be identified among a large and diverse sample; whether developmental patterns in correlational reasoning were similar regardless of problem context; and whether developmental patterns in correlational reasoning were similar for subjects of similar developmental levels regardless of educational level. Data from students in grades 6-13 (N=2282) were collected using two parallel forms of Tobin and Capie's Test of Logical Thinking (TOLT). Two of the ten items which measured correlational reasoning abilities were analyzed for the study, and common response patterns were identified among the respondents. Included among the results was the finding that response patterns were more predictable and stable across developmental level than educational level. Error patterns are also discussed. (CS)

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PATTERNS OF REASONING: CORRELATIONAL THINKING

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Paper presented at the annual meeting of the National Association for Research in Science Teaching, Grossinger, New York.

April, 1981

SE 034 821

PATTERNS OF REASONING: CORRELATIONAL THINKING

Cognitive development has become an increasingly important area of study for educators and psychologists. Much interest undoubtedly reflects a simple need to understand the evolution of thought processes from childhood to adolescence. Other interest stems from the knowledge that cognitive development has great potential for helping researchers understand the effectiveness of specific teaching and learning strategies. Several science educators have cited fromal reasoning ability as an important mediator of achievement (e.g., Cantu and Herron, 1978; Goodstein and Howe, 1978). Five reasoning modes are identified as having particular relevance to science instruction: controlling variables, proportional reasoning, probabilistic reasoning, combinatorial reasoning, and correlational reasoning.

Correlational reasoning is necessary for assuring intelligent decisions regarding many aspects of science as well as daily life. The correlation between ambient temperature and plant activity and the relationship between air pollution and various lung ailments are examples. Studying prevalent thought patterns used in correlational reasoning is thus important to future development in curriculum and teaching methodology. The purpose of this paper is to examine student responses to several correlational reasoning problems and to illuminate common patterns of reasoning behavior.

RELATED RESEARCH

Only a few reports dealing with correlational reasoning can be identified in the literature. In one important study Adi, Karplus, Lawson

and Pulos (1978) conducted individual interviews with 80 secondary students using two correlations problems. Students were asked, for example, whether there was a relationship between the size of rats (fat or thin) on an exotic island and the color of their tails (red or green). They were then given a set of data cards representing a sample of rats caught on the island. Each card consisted of a single case, either a fat green rat, a fat red rat, a thin green rat or a thin red rat. The data from the cards could be best visualized in a 4 cell matrix.

The authors classified student responses into one of four categories. Category NR responses indicated that a student did not consider the relationship between the two salient variables. This was the most rudimentary response. Category TC indicated that the response considered data in only two of the four data cells. Category FC indicated data from all four cells were used to make two comparisons, but that a true correlational response was lacking. Category CO indicated that a correct correlational response was made which considered a quantitative comparison using all four cells.

Adi, et al (1978), found that twelfth graders in their sample performed better than ninth graders. They also hypothesized that the development of the reasoning modes of probability and proportionality were necessary prerequisites for the appearance of operational correlational reasoning. They argued that when students compare "the number of confirming cases to the total number of cases, it reflects the notion of probability," and that proportions "contribute to the conversion of fractions to percents" for correct problem solution.

In a later study Karplus, Adi and Lawson (1980) gave pencil and paper problems similar to those used by Adi, et al (1978), to over 500 students in grades 6 through college sophomores. Students were asked to provide written justifications for thinking a correlation existed between two variables in a problem (e.g., size of mice and tail color). Using a similar categorization system as Adi, et al (1978), they found a gradual development of correlational reasoning from sixth grade to college where CO logic was not used by any sixth grader but was used by almost 50% of the college sample. While the author's mention the difficulty of expressing one's thoughts in writing, they only intimate this might have particularly affected the younger students.

The lack of other studies supporting the above results and the availability of over 2000 responses to problems similar to those described above, led to the present study.

PROCEDURE

Data from 2282 subjects in grades 6-13 were collected using the Test of Logical Thinking (TOLT) (Tobin and Capie, 1981). Approximately 1627 used Form A and the balance used Form B. The characteristics of these test forms have been well-documented by their developers (Capie and Tobin, 1980). Each form consisted of ten items, two each for proportional reasoning, and identification and control of variables.

Figure 1 is a correlational reasoning problem from TOLT Form A which deals with the body size and tail color of mice. Students read the problem statement and then respond yes or no whether "fat mice were more likely to have black tails and thin mice were more likely to have white

tails." They then chose a reason from among five which justifies their thinking. The two part format lessened the possibility of chance correct responses.

TOLT Form A also includes a problem dealing with attributes of fish (body size and width of lateral stripes). Form B includes problems dealing with different colored gumballs and two attributes of dogs (body size and presence or absence of spots).

Both the mice and fish problems were patterned after those used in Adi, et al (1978), and Karplus, et al (1980). The only major difference was the method of testing (multiple choice format vs. interview vs. written justifications). In creating TOLT, Tobin and Capie first gave each problem to students and had them provide written justifications for their yes or no answer. They then grouped ~~like~~ responses and used the Adi, et al (1978), classification scheme to come up with the five reasons. Each justification on the TOLT correlations problems represents a different reasoning pattern (NR, TC, FC or CO), with one pattern being repeated. This original analysis supported the existance of the different levels of reasoning. Figure 1 also includes the level (NR, TC, FC or CO) for each reason on the mice problem.

The most common combinations of responses and justifications were selected for additional study. Less common responses seemed to be chosen as random guesses.

RESULTS

Across all subjects taking TOLT Form A (N=1620) 56% answered the mice item correctly and 57% answered the fish item correctly. Among

subjects taking TOLT Form B (N=658), 78% answered the gumball problem correctly and 67% answered the dog item correctly. These percentages show a higher than expected degree of success.

The justifications subjects selected were categorized using the NR, TC, FC and CO nomenclature developed by Adi, et al (1978). A breakdown of type of response by correlational item for all subjects is contained in Table 1. The majority of incorrect responses for the fish and mice problems were in the NR category (about 21% of the total responses). It should be noted that these two items each contained two NR foils, which may have inflated the percentage in this category. It seems unlikely that this would affect a relative ranking of the responses, however. The patterns for gumball machine and spotted dogs problems are not as clear. Responses to the gumball problem showed that a majority of incorrect responses were in the FC category. The dog problem resulted in a high number of TC responses.

A sample from the population taking TOLT Form A was available for further study. These 899 subjects were composed of approximately equal numbers of middle school, high school and college subjects. The response patterns of each academic group may be found in Table 2. The percentage of correct responses, regardless of developmental level, increased substantially from middle school to high school (35% to 57%), but did not continue to rise in the college group. The number of NR responses decreases from middle school to high school but surprisingly increases at the college level. The number of responses in the other categories decreases from middle school to college. One could speculate that college students read too much into these problems perhaps utilizing knowledge not

necessary for providing a correct solution (e.g., genetic principles and species characteristics). More research is needed on the high proportion of NR responses in the college sample.

Students in this sample were also categorized developmentally by TOLT scores (Table 2) as either concrete, transitional or formal. Within each developmental level the responses of subjects of varying academic levels were compared. Students categorized as concrete selected a high percentage of NR responses. The FC category was popular with middle and high school students while less so with college respondents. Since the number of college students labeled concrete was very small (N=12), it is difficult to make generalizations among all three academic groups comprised of concrete subjects. The percentage of concrete subjects correctly solving an item was approximately the same in all groups.

Examination of the transitional subjects revealed a decrease in the number of NR responses and a substantial increase in correct responses. Other categories changed little. Formal students in all academic levels chose the correct response most often, while selection of other categories was approximately equal. Again, it is interesting to note the occurance of many NR responses in the college sample. Approximately 26% of the college students categorized as formal operational selected the NR category. Upon examination of the two TOLT A items one finds responses for the mice problem to be responsible for this phenomena.

It is possible to compare these results with those of Karplus, et al (1980). In the Karplus study none of the sixth graders correctly answered either of the correlational items, while only eight percent of the eighth graders correctly answered at least one of the correlational items.

Approximately thirty-five percent of the middle school students in the present study (Grades 6-8) chose a correct response. Similar comparisons between the two studies yields a definite pattern. Younger students generally scored higher in the present study than in Karplus; older students scored equally as well. A possible explanation for this discrepancy lies in the format of the items. Karplus required students to construct written answers, while TOLT used a multiple choice format. Many researchers (Travers, 1977) have noted that reading and identifying an answer, as done in TOLT, is much easier than constructing an answer.

DISCUSSION

The most important question raised in this study involves the differences between the Karplus', et al (1980) results and the present data. The multiple choice format of TOLT allows for chance correct responses (a 1 in 10 possibility), but also penalizes the poor or non-reader. The latter problem would be especially hard on the middle school subject in our sample. Yet only 4% of Karplus' middle school aged subjects answered the items correctly, while 35% of comparable subjects in the present study did so. One reasonable explanation for this difference is that the written justifications, as used by Karplus, placed an added cognitive burden on subjects, which caused some error in measurement. Of course, a strict Piagetian researcher might argue that unless a subject can formulate a justification by herself, that she does not exhibit true correlational reasoning patterns. When the percentage of correct responses are reconstructed from data presented by Adi, et al (1978) only 15% of the high school subjects (no middle school students were involved) show full CO reasoning

patterns. Subjects in this study were individually interviewed. This result further clouds the issue.

A logical analysis of the problem would assume that correlational reasoning is not an "all or nothing" phenomenon. Students able to select a correct response from among several possibilities, certainly show a basic understanding of that ability. Those able to verbally state or write a justification might be showing more advanced or at least different abilities. It would be interesting to compare subjects' correlational reasoning abilities using the three different item formats--individual interview, written response and multiple choice. A study of this type would lead to a better understanding of the development of correlational reasoning.

Approximately 68% of the subjects taking Form A and 87% of those completing Form B were categorized as formal by their TOLT scores. Furthermore, a higher percentage of students correctly completed Form B correlational items than corresponding Form A items. One could speculate that the level of item difficulty varied greatly or the student samples are not comparable. Data concerning the academic level of Form B subjects was not available for this study.

The exceedingly high success rate on the gumball item could possibly be attributed to its construction. Students are given the number of cases of the attribute of concern (color) while in all other correlational items students must count the number of cases from a picture. In addition, the correct justification is in simple sentence form while CO responses for all other correlational items contain numerical ratios in a complex format. The other Form B item, spotted dogs, is very similar in construction to

those of Form A. The higher success rate on spotted dogs, however, supports the notion of group differences in the two student samples.

In conclusion, while the present data suggest a higher prportion of the school age population are able to deal with correlational reasoning problems compared to other studies, there is still a need for attention to correlational logic in the schools. Presenting students with the opportunity to develop correlational reasoning abilities should not be solely the responsibility of the science educator, however. As Karplus, et al (1980) suggest, curricula must integrate the use of formal reasoning modes into the various facets of school study. It is likely that teaching mathematics and science as separate entities does not provide optimum facilitation for the acquisition of these skills.

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The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?

a. Yes

b. No

Reason

1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails. (CO)

2. Some of the fat mice have white tails and some of the thin mice have white tails. (NR)

3. 18 mice out of thirty have black tails and 12 have white tails. (FC)

4. Not all of the fat mice have black tails and not all of the thin mice have white tails. (NR)

5. 6/12 of the white tailed mice are fat. (TC)

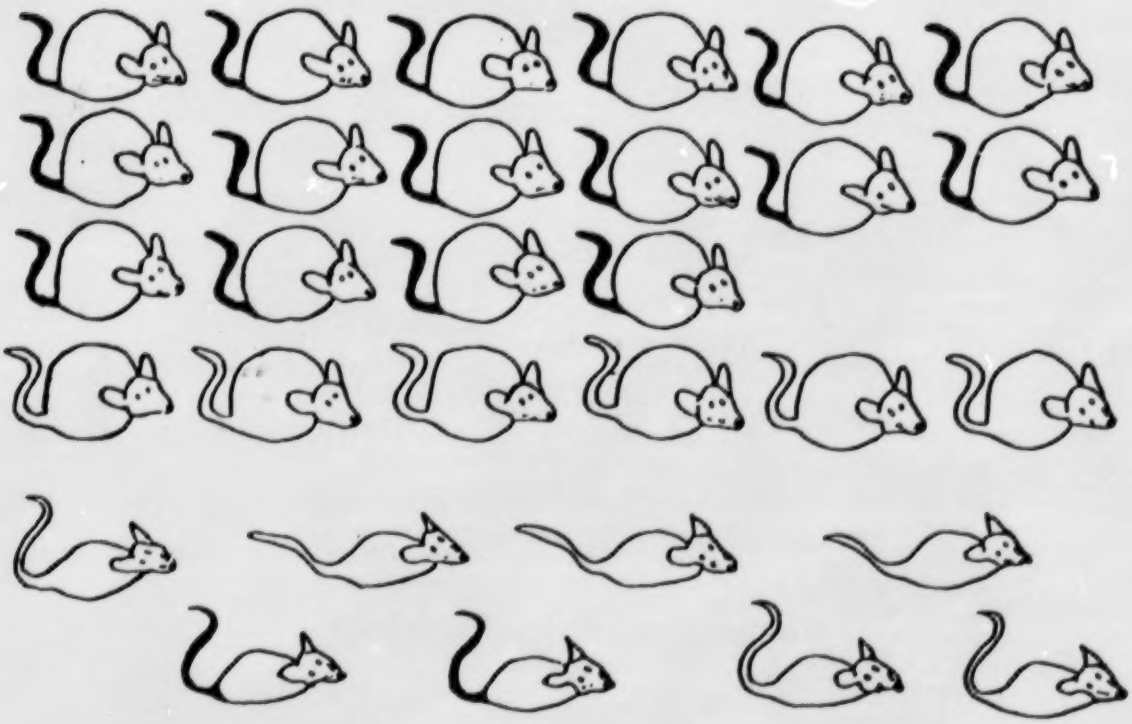

Figure 1. The mice--a correlational reasoning problem from TOLT.

Table 1

RESPONSE PATTERN (%) FOR ALL SUBJECTS ON CORRELATIONAL ITEMS

	NR	TC	FC	CO
The mice (n=1620)				
yes	6.6	2.8	12.2	55.8*
no	13.6	3.0	0.9	4.0
TOTAL	20.2	5.8	13.1	59.8
The fish (n-1621)				
yes	1.2	0.9	0.9	6.2
no	20.9	7.8	5.1	56.5*
TOTAL	22.1	8.7	6.0	62.7
The gumball (n=658)				
yes	0	2.2	13.1	77.8*
no	0.9	3.8	0.9	1.1
TOTAL	0.9	6.0	14.0	78.9
The spotted dog (n=657)				
yes	0.2	2.7	0.8	8.5
no	5.8	11.1	1.8	66.8*
TOTAL	6.0	13.8	2.6	75.3

* = correct response

Table 2

PERCENT OF RESPONSE TYPES CHOSEN BY SUBJECTS OF VARIOUS ACADEMIC AND COGNITIVE LEVELS

Developmental Level	Educational Level	Type of Response				
		NR	TC	FC	CO* incorrect	CO correct
Concrete	middle school n=108	55	11	22	6	6
	high school n=56	52	4	24	11	8
	college n-12	75	4	13	0	8
	Subtotal (n=176)	55	9	22	7	7
Transitional	middle school n=88	30	14	17	5	34
	high school n=50	25	7	30	4	35
	college n=37	41	11	11	9	27
	Subtotal (n=175)	31	11	19	5	33
Formal	middle school n=83	7	7	7	5	74
	high school n=210	9	6	6	6	74
	college n=255	26	4	3	5	61
	Subtotal (n=548)	17	5	5	5	68
Total	middle school n=278	35	15	11	4	35
	high school n=315	19	13	6	5	57
	college n=304	29	4	5	4	55

*Indicates student selected the correct reason but the incorrect answer (yes or no).